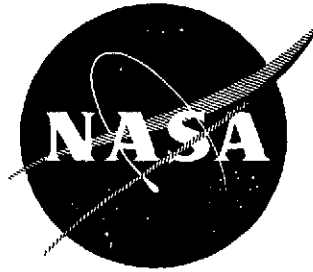


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EXECUTIVE SUMMARY
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SOME ECONOMIC BENEFITS OF A SYNCHRONOUS EARTH OBSERVATORY SATELLITE

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16. Abstract An analysis has been made of the economic benefits which might be derived from reduced forecasting errors made possible by data obtained from a synchronous satellite system which can collect earth observation and meteorological data continuously and on demand. The costs of establishing and maintaining such systems are not considered, but certain user costs directly associated with achieving benefits are included. In the analysis, benefits have been evaluated which might be obtained as a result of improved thunderstorm forecasting, frost warning, and grain harvest forecasting capabilities. The analysis for the benefits in these areas have not been concerned with details of the satellite configuration or operational methods, but the anticipated system capabilities have been used to arrive at realistic estimates of system performance on which to base the benefit analysis. The major emphasis of the analyses has been on the benefits which result from system forecasting accuracies. Benefits from improved thunderstorm forecasts are indicated for the construction, air transportation and agricultural industries. The effects of improved frost warning capability on the citrus crop are determined. The benefits from improved grain forecasting capability are evaluated in terms of both U.S. benefits resulting from domestic grain distribution and U.S. benefits from international grain distribution.					
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PREFACE

This report summarizes the activity conducted during a four-month study under Contract NAS5-20021 to evaluate the potential economic benefits of several representative applications of a synchronous earth observatory satellite. These applications were selected from earth resources applications identified in a previous ERIM study under Contract NAS5-21937 and from meteorological applications identified in a parallel study (also for NASA/GSFC) conducted by the Space Science and Engineering Center of the University of Wisconsin.

The work was performed jointly by the Environmental Research Institute of Michigan and ECON, Incorporated, with ERIM as the prime contractor. Mr. Donald S. Lowe acted as Principal Investigator and Mr. Irvin J. Sattinger participated as Project Engineer. For ECON, Mr. Joel S. Greenberg was Project Director and Dr. Ranendra K. Bhattacharyya was Principal Investigator. Dr. Louis Walter, Goddard Space Flight Center was Technical Officer for the project, which was directed by Mr. Laurence T. Hogarth, Systems Analysis Office.

ERIM concentrated its effort on evaluation and estimation of remote sensing capabilities and on specifying methods of applying these capabilities to the economic activities under study. ECON was fully responsible for development and application of the economic methodology used to estimate potential benefits of the applications. ERIM did not participate to any significant extent in the thunderstorm warning application; the complete study effort for this application was undertaken by ECON.

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

High resolution synchronous equatorial meteorological satellites, as exemplified by the recently-launched Synchronous Meteorological Satellite (SMS), and proposed earth observation satellites (SEOS) make it possible, in the absence of cloud cover, to continuously or on a demand basis observe specified points on or above the earth's surface. Three representative applications were selected for economic evaluation from the many potential uses for such satellites identified in two previous NASA-supported surveys.^[1,2] The applications are (1) thunderstorm forecasting for the construction, air transportation, and agricultural industries, (2) frost warning for the citrus-growing industry, and (3) grain crop forecasting. These selections were made for one or more of the following reasons: they seemed likely to show substantial benefits in a variety of economic sectors, the analysis would be facilitated by the availability of existing economic models, they appeared to be technically feasible with moderate research and development effort, and/or they took advantage of both the meteorological capability and the earth resources capability of SEOS. As an additional consideration, the applications were selected on the basis that the synchronous satellite would be located above the Western Hemisphere.

For each of the applications, the estimated annual savings and present worth of benefits are summarized in Table 1. Since the study was limited in scope, not all of the potential benefits even within the selected three study areas could be considered exhaustively.^[3]

Three types of weather forecasts are considered and are denoted as Conventional, SMS, and SEOS. Conventional, as its name implies, refers to the capability for forecasting systems currently in operational use. SMS forecasts are assumed to have the accuracy (anticipated by NASA) of

TABLE 1 TOTAL INDUSTRY AND SOCIETAL BENEFITS
FOR APPLICATION OF SYNCHRONOUS SATELLITE
(1974 Dollars)

	POTENTIAL ANNUAL SAVINGS (Millions of Dollars)		ESTIMATED ANNUAL REALIZABLE SAVINGS (Millions of Dollars)		PRESENT WORTH OF GROSS BENEFITS(2) (Millions of Dollars)	
	SMS (Relative to Conventional)	SEOS (Relative to Conventional)	SMS (Relative to Conventional)	SEOS (Relative to Conventional)	SEOS Relative to Conventional 1980 Launch	1985 Launch
Thunderstorm Forecasting						
Construction industry ⁽¹⁾	767 ⁽³⁾	1,366 ⁽³⁾	230 ⁽⁴⁾	410 ⁽⁴⁾	1,030	640
Air transportation industry	20	40	20	40	115	70
Agriculture industry	420	629	90 ⁽⁴⁾	135 ⁽⁴⁾	340	210
Frost Warning						
Citrus crop (Florida and California)	4	8	4	8	23	14
U.S. Grain Crop Forecasting						
International market		53		53	150	90
U.S. domestic market		36		36	100	60

- (1) These estimates reflect the societal benefits which include the savings not only of the construction industries, but of the workers and of the equipment rental agencies as well. Hence these benefit figures remain unchanged irrespective of the varying nature of the contracts between construction industries and workers' unions regarding the wages on storm days when work is suspended.
- (2) Estimates of present worth are based on a schedule involving a 7-year time interval between the experimental satellite launching and the start of an operational capability. An additional 5 years are allowed to achieve the full potential of realizable benefits. Realizable benefits take account of anticipated degree of implementation by the user. Present worth of the continuing stream of benefits is computed using a 10 percent discount rate.
- (3) \$79 billion of weather sensitive construction are projected for 1980 based upon reported 1964 weather caused losses and GNP and construction industry growth trends and of a total construction worth of \$176 billion.
- (4) Realizable savings equal potential annual savings multiplied by estimated fraction of the savings which would be achieved through proper user implementation. Implementation fraction estimated as 0.3 for construction industry and 0.0, 0.2 and 0.5 for agriculture industry savings associated with rescheduling harvesting, standing water and loss of spray, respectively.

a system utilizing SMS technology. SEOS forecasts are based upon the projected capability of a SEOS-type system. Estimates of the capabilities of all of these weather forecasting systems were provided by NASA/GSFC scientists.

2.0 THUNDERSTORM FORECASTING

The use of a synchronous satellite for improved forecasting of thunderstorms was selected as one of the meteorological applications because it seemed likely to offer a high level of benefits both in dollars and in lives for a variety of economic activities.

2.1 CONSTRUCTION INDUSTRY

Construction industry expenses, which constitute more than 10 percent of the gross national product, are sensitive to bad weather. Thunderstorm forecasting benefits are considered to be the cost savings which result in the areas of perishable material, wages, equipment, and overhead and profit from using improved thunderstorm forecasts and pursuing an optimal course of action in the face of false alarms, misses, and operational constraints. Since consideration has been given to construction workers' lost wages, the estimated benefits in Table 1 are actually the net societal savings which result from the construction firms pursuing their optimal work-no-work policies.

Not all users will utilize the improved forecast data, nor, if they do rely on the improved data, will they necessarily pursue the optimum course of action strategy. Nor will all users who utilize the improved forecast data in determining their course of action utilize the data as soon as they become available. Thus, the estimated actual benefits differ from the potential benefits in both magnitude and time of realization. Based upon existing industry weather forecasting use patterns, the achievable benefits are estimated to rise to a maximum of 30 percent of the potential benefits after an operational system has been in existence for 5 years.

2.2 AIR TRANSPORTATION INDUSTRY

The air transportation industry, consisting of general aviation (personal, recreational, etc.), commercial aviation (domestic and international carriers with both scheduled and non-scheduled flights), and military aviation, is affected by the accuracy of thunderstorm forecasts. Accidents are the principal source of weather-related loss in general aviation. With improved thunderstorm forecasts, benefits will accrue in two areas: (1) as the miss rate decreases, there will be fewer accidents due to faulty forecasts, and (2) as the false alarm rate decreases, thunderstorm forecasts will be taken more seriously and there will be fewer weather-related accidents that are not directly due to faulty forecasts (i.e., accidents that occur because fliers often take chances in the face of a storm forecast on the assumption that it would turn out to be a false alarm). Each accident results in both physical damage (to the aircraft) and lost lives. It has been assumed that the average present value of a lost life (based upon average remaining productive earning power) is \$100,000. Since the air transportation industry currently uses weather forecast data on a routine basis, estimated benefits were computed based on implementation levels reaching 100 percent.

2.3 AGRICULTURE INDUSTRY

Improved thunderstorm forecasting will produce benefits by making it possible to minimize losses in certain agricultural operations. Preventive actions can be taken to circumvent the effects of storms by rescheduling spraying and harvesting and adjusting irrigation policies. In establishing the present worth of potential agricultural benefits, each of these cost saving areas was considered separately, since each area has a different degree and rate of implementation.

3.0 FROST WARNING

The application of improved weather forecasting for protection against frost damage to the citrus fruit industry was selected for analysis because it lends itself to detailed and clear-cut analysis of the manner in which improved data from a synchronous satellite can

specifically improve an economically-significant operation. The basic methodology for evaluating frost warning benefits is the same as that employed for evaluating thunderstorm benefits -- i.e., the consideration of false alarms and misses and action-no-action alternatives. Frost warning benefits associated with reduction in false alarms are the savings of labor and fuel which would have been unnecessarily expended with less accurate weather forecasting. Reduction of misses would result in further savings because of reduction in crop damage. The savings would result from the improved ability of SMS or SEOS forecasting to indicate the need for taking protective action. Only those benefits associated with the citrus crop (oranges, tangerines and grapefruit) for Florida and California are considered. This portion of the citrus crop constitutes approximately 45 percent of the total U.S. fruit production. Since the citrus crop industry is one of the agricultural industries currently using weather forecast data on a routine basis, it is assumed that 100 percent of the potential cost savings may be realized in practice through user implementation.

4.0 GRAIN CROP FORECASTING

The third application was that of grain distribution. This application takes advantage of the earth resources capability of a synchronous satellite as distinguished from its meteorological capability. Previous work performed at ECON, Inc. on economic models of grain distribution indicated that the improved knowledge derived from SEOS could show major economic benefits for worldwide performance of food distribution. The economic benefit study concentrated on the distribution of wheat, which has the greatest production value among all the staple crops of the world.

An optimum space system for providing improved grain forecasting will use data obtained from a synchronous satellite along with data from ERTS or other low-altitude satellite systems. The major advantage of SEOS which makes it uniquely valuable for crop forecasting is its ability to obtain critically-timed looks at a given area. Techniques which use space data can result in improved crop forecasting through (1) the use

of new types of data, (2) increase in sample size, (3) earlier detections of growth trends, (4) accurate determination of incremental changes, and (5) indication of possible discrepancies in ground survey data. Although the calculation of benefits made in this report is based on the use of space-acquired data, the benefits determined are valid for any other system that would provide similar data in a timely manner.

Because of the current lack of detailed information concerning the effectiveness of methods of improving grain crop forecasting with remote sensing methods, it is not possible at this time to provide precise estimates of forecasting improvement which could be achieved with space-acquired data. Accordingly, benefits were calculated for a condition where current production forecasting errors are reduced by 50 percent. It would be advisable to consider the computed benefits as only a general indication of magnitude of benefit which may be achieved. For example, under certain conservative assumptions concerning sensor performance, the errors in forecasting of existing ground-based survey methods might be reduced by only 20 percent throughout the growing season.

Grain distribution benefits arise from smoothing out the flow of product, from grower to user, resulting from improved forecasts. The physical interpretation of the benefit calculation is that with a more accurate foreknowledge about forthcoming crops, it is possible to make a better allocation of the consumption of commodities over time, thus ensuring a smoother flow. A smooth flow of commodities is more beneficial than an irregular flow because the value of increments to consumption is not constant. It decreases as the quantity consumed increases.

Based on space observation of only the U.S. wheat crop, both U.S. benefits resulting from domestic wheat distribution and U.S. benefits resulting from international wheat distribution are considered (see Table 1). These benefits are interrelated and not simply additive. Bounds for their combination can be considered as the larger of the two (the lower bound) and the sum of the two (the upper bound). In analyzing the case for the domestic market, the U.S. is considered as a water-tight

region with no flow of wheat to foreign countries. Thus the domestic consumption of wheat based on the forecast of domestic production is considered, while the effect of erroneous forecasts in the wheat production of other countries and their effects on the U.S. domestic consumption are ignored.

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